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Khirbat al-Mana'iyya: an early Islamic-period copper-smelting site in south-eastern Wadi 'Araba, Jordan

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Abstract

Recent excavations in south-eastern Wadi 'Araba in Jordan have revealed the first early Islamic-period copper-smelting site known in the eastern side of the valley, which extends south of the Dead Sea to the Gulf of 'Aqaba. Five test pits were excavated in 2012 at Khirbat al-Mana'iyya, a prominent copper-smelting camp in south-eastern Wadi 'Araba, Jordan. The results of these excavations demonstrate that the site was primarily active in the seventh–ninth century AD. Its distance from the copper sources of south-west 'Araba suggests that its location was chosen based on proximity to wood and water resources, rather than copper ore deposits. The discovery that the site dates to the early Islamic period has implications for previous and future work in south-east 'Araba. In particular, it challenges the common—until now—view of the region as virtually devoid of settlement during this period.

KEYWORDS

'Abbasid, copper, early Islamic, Jordan, mining, smelting, southern 'Araba

1 | INTRODUCTION

Prior to the late 1980s, the existence of an early Islamic period (c.600–1000 AD)¹ copper industry in Wadi 'Araba—the lowland valley between the Dead Sea and the Red Sea—was entirely unknown.² This changed after radiocarbon evidence demonstrated first, that a Late Bronze Age

furnace at Timna Site 2 had been reused in the eighth century AD,³ and second, that one of the large slag mounds at the Be'er Ora smelting camp (Arabah Expedition Site 28) dated entirely to the early Islamic period (Rothenberg, 1988). Be'er Ora had previously been dated to the Roman and Byzantine periods (Rothenberg, 1962: 62; 1972: 222),

¹In this paper we use the archaeological periodisation developed by Whitcomb (1992; see also Jones, Levy, & Najjar, 2012: fig. 1), who divides the early Islamic period into two sub-periods: the early Islamic I (AD 600–800) and early Islamic II (AD 800–1000).

²Discounting Glidden's (1941) assertion that Khirbat Nuqayb al-Asaymir—which is, in fact, a middle Islamic period site—dated to the early Islamic period. This was based on a misreading of Glueck (1940) and does not seem ever to have been taken seriously (see Jones et al., 2012: 72, n. 5).

³Furthermore, the current study strengthens the view of U. Avner and Magness (1998), Ben-Yosef et al. (2012), and U. Avner (2014) that this furnace—Furnace Z—as well as some others at the site, were constructed in the early Islamic period, as they demonstrate similar technological features to the smelting installations at Khirbat al-Mana'iyya, unknown in smelting sites dated to the Late Bronze Age (contra Erickson-Gini, 2014). Even if this were not the case, however, it is certain that at least two of these furnaces were reused during the early Islamic period (see radiocarbon dates nos. 78–79 in Avner U. 2014: 146, table 1).

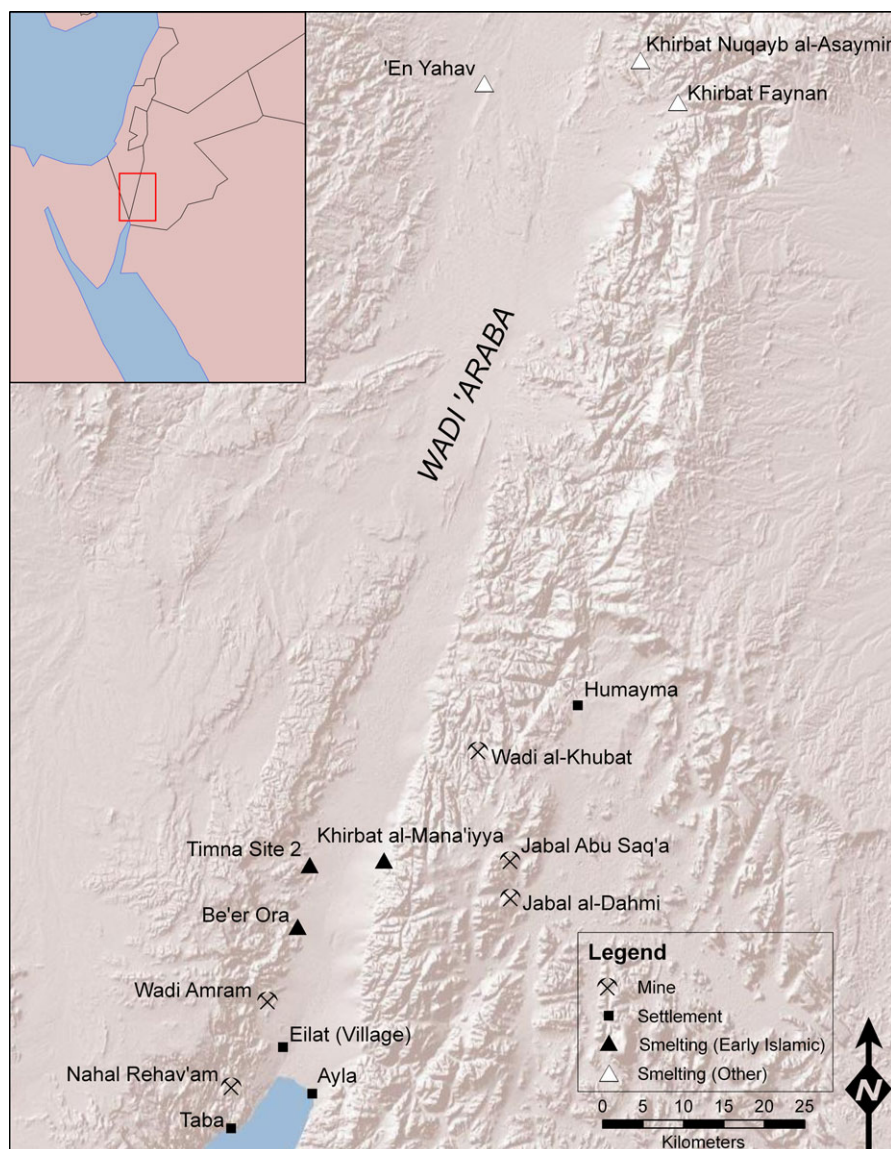


FIGURE 1 A map of selected sites in Wadi 'Araba mentioned in the text (map: IWNJ, base map: © 2014 Esri) [Colour figure can be viewed at wileyonlinelibrary.com]

and the realisation that it was primarily active during the early Islamic period prompted a re-evaluation of the archaeology of southern 'Araba. In the decades since, it has become clear that Be'er Ora is not a unique outlier, but rather part of an extensive system of settlements in south-western 'Araba forming the industrial 'hinterland' of the early Islamic port of Ayla, modern 'Aqaba, on the Red Sea coast (Fig. 1; Avner U. & Magness, 1998; Damgaard, 2009; Jones, Najjar, & Levy, in press; Nol, 2015; Whitcomb, 2006a). Until now, it seemed that evidence for this settlement system was limited to south-western 'Araba, in modern southern Israel. This paper, however, presents evidence from a pilot season of excavations at Khirbat al-Mana'iyya—the first early Islamic-period copper-smelting site identified in south-eastern 'Araba, in modern Jordan—conducted in 2012 by the University of California, San Diego Edom Lowlands Regional Archaeology Project (ELRAP).

1.1 | Distinctive features of the early Islamic-period copper industry

The early Islamic copper industry is marked by the emergence of a quite distinctive smelting technology. The slag pits of the domed bowl furnaces⁴ used during this period were designed to cast a central hole in circular plates of slag (Rothenberg, 1990: 57). This central hole presumably made the plates easier to discard or transport to processing areas by allowing them to cool faster and to be removed in one piece (Fig. 2a). Additionally, the central hole may have made it easier to break up the slag plates for reprocessing and to recover copper prills. The central hole on the ring

⁴The term 'bowl furnace' is not meant to imply that these furnaces would have been open. As demonstrated by examples from Be'er Ora (Rothenberg, 1999: 166, 167, fig. 27) and al-Nuqra (North) (de Jesus et al., 1982: 72, 74), these furnaces probably had a dome-shaped superstructure.



FIGURE 2 Partial ring slags from Khirbat al-Mana'iyya: (a) a relatively complete example. The string is wrapped through the cast-in centre hole; (b) close-up of the top of a ring slag. The north arrow points to an area of flow-banding, and prominent flow-banding is also visible above the scale bar (photos: T.E. Levy) [Colour figure can be viewed at wileyonlinelibrary.com]

slags discussed here is usually *c.* 20 cm in diameter, but on some examples, such as the one presented in Figure 2a, this can be under 10 cm. The entire ring slag is usually between 60 and 80 cm in diameter, weighing *c.* 80 kg. These slags can also be distinguished by their prominent, often rather sharp flow-banding (Fig. 2b). This feature has not been observed on earlier slags and is present only rarely on the middle Islamic-period slags—which are not ring slags—found in the Faynan region. The available evidence indicates that Rothenberg (1990: 60) is probably correct in suggesting that the central hole in ring slag ‘seems to have been a locally developed metallurgical tradition of the Arabah’, even if it is also the case, as suggested by Bachmann (1980: 114), that the use of lime flux reflects an imported smelting technology. It is difficult to determine whether this type of slag is present nearby in the Hijaz, in modern Saudi Arabia, due to the limited amount of recent archaeological research in the region and summary reporting of previous investigations (for earlier surveys, see Kisnawi, de Jesus, & Rihani, 1983: 79; Sabir 1991). Farther to the east, however, excavations at al-Nuqra (North)—a

large, early Islamic-period copper-smelting site in the western Najd (Fig. 3)—have produced evidence of the use of a similar furnace technology, but with slag pits that were not designed to cast in the central hole found in ring slag (de Jesus et al., 1982: 71–72, 74, pls. 87A, 88A, 97B). Recent work in the region of al-Baha, in the south-western Hijaz, has produced similar results (Al-Zahrani 2014). Further afield, furnace technologies are less similar. In eastern Arabia, for example, archaeological work at several sites in Oman has demonstrated the use of a shaft furnace technology rather different from the domed bowl furnaces in use in southern ‘Araba and north-western Arabia (Ibrahim M.M. & ElMahi, 2000: 212–213; Weisgerber, 1987: fig. 76).

Assuming ring slag is unique to the ‘Araba, its origins are not entirely clear. Rothenberg (1990: 60) argued that it demonstrates continuity of smelting traditions developed during the Late Bronze Age. U. Avner and Magness (1998: 52–53, n. 7), on the other hand, argue that ‘current evidence suggests that these slag cakes did not appear before the Nabataean period’, and Ben-Yosef et al. (2012: 59, n. 14) argue that while solid slag cakes first appear in the Iron Age (late tenth century BC), the cast-in hole does not appear earlier than the Nabataean period.

U. Avner and Magness’s (1998) Nabataean period date for ring slag is probably too early.⁵ Although evidence for copper production during this period is sparse in southern ‘Araba, ring slag is not found at the large Roman slag mound at Khirbat Faynan (Hauptmann, 2007: 94–96) or at the much smaller site of ‘En Yahav, *c.* 25 km to the west, where smaller-scale Roman period smelting seems to have taken place (Yekutieli, Shilstein, & Shalev, 2005; see also Rothenberg, 1967: 129–129). Instead, the early Islamic furnace technology of southern ‘Araba seems to be unique to this period, different from both the preceding Roman

⁵They state that, ‘ceramic and Carbon-14 evidence indicates that although this site [Be’er Ora] first became active during the Nabataean period and was used during the Mamluke period, the most intensive activity took place during early Islamic times’ (Avner U. & Magness, 1998: 42–43). To date, no Nabataean or Roman period radiocarbon dates have been published for Be’er Ora (a summary of published dates for Be’er Ora can be found in Avner U., 2014: 146, table 1, nos. 80–88), suggesting that the Nabataean date relies on ceramic evidence. Linking these sherds to copper production activity is more difficult, however. As in Faynan, we would argue that reliance on direct dating of copper smelting remains is safer than assuming copper production during every period of occupation (see e.g. Jones, Najjar, & Levy, 2014). Recent research does suggest that the mines in Wadi ‘Amram were active in the Nabataean period, but the associated smelting sites are not yet known (Avner U. et al., in press: 156, table 10.1, 159, 161, 173). Assuming that copper was produced at Be’er Ora or elsewhere in south-western ‘Araba during the classical period, we know virtually nothing about the furnace technology that would have been used—certainly, we do not have enough evidence to suggest that ring slag emerged in this period.

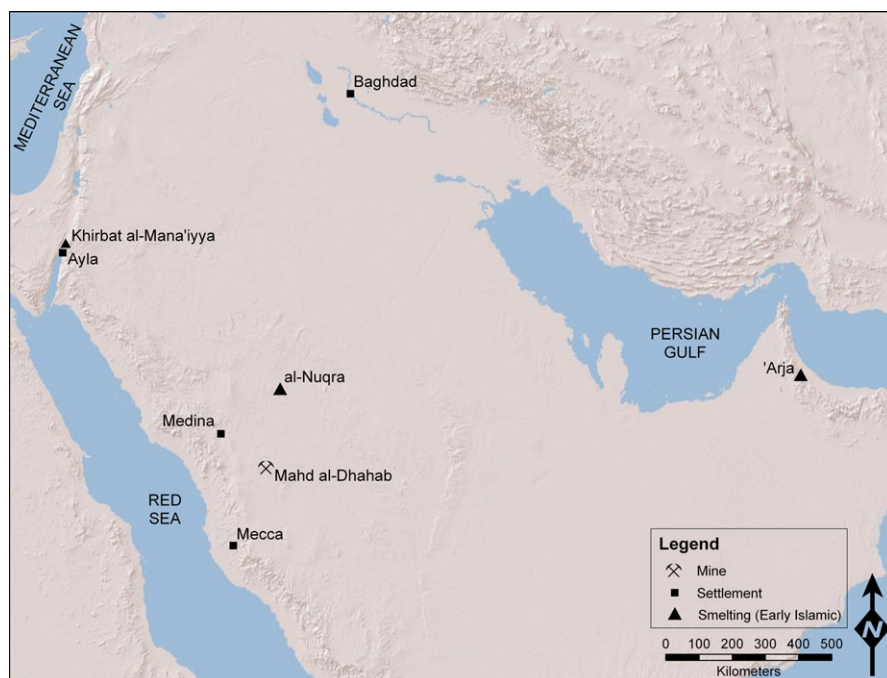


FIGURE 3 A map of sites in Mesopotamia and Arabia mentioned in the text (map: IWNJ, base map: © 2014 Esri) [Colour figure can be viewed at wileyonlinelibrary.com]

technology and possibly the middle Islamic technology that followed, which has much in common with the shaft furnace technology of early Islamic Oman (see Hauptmann, 2007: 127; Jones, 2016: 116–119; Levy et al., 2012: 428–429).⁶

1.2 | The site and history of exploration

Khirbat al-Mana'iyya (Fig. 4)—or Wadi al-Nukhayla 1—is a c.0.5 ha copper smelting camp located to the south of Wadi al-Nukhayla (Ar. for “wadi of palm trees”), c.3.5 km south of the modern Bedouin village of al-Qatar. The wadi’s name could not be found on maps of the region—the closest wadi mentioned by name on the geology map is Wadi al-Wa’ra (Ibrahim K.M.d.K., 1989)—but there is a Jabal al-Nukhayla several kilometres to the east, and the name of the wadi is probably associated with this feature.⁷ The three slag mounds at the site contain an estimated “several hundred tons” of slag (Ben-Yosef, 2012: 64), which is more than any site in the Timna Valley, but less than Be’er Ora, which is estimated to contain 5000 tons of slag (Avner U. & Magness, 1998: 42).



FIGURE 4 A photograph of Khirbat al-Mana'iyya, facing roughly east. The dark patches in the centre of the photo are slag mounds (photo: E. Ben-Yosef) [Colour figure can be viewed at wileyonlinelibrary.com]

Ben-Yosef (2012: 64) points out the similarity of the site’s name to that of the Timna Valley, which in Arabic is known as al-Mana'iyya (see e.g. Glueck, 1935: 42–45). The biblical name ‘Timna’ has an association with the clans of Edom (Genesis 36: 40–43; 1 Chronicles 1: 51), and because it sounds like Mana'iyya it was the name chosen during the ‘Hebraization’ of place names early in the history of the modern state of Israel (Ben-Yosef, 2012: 64, n. 6; on this process generally, see Benvenisti, 2000). The Arabic toponym al-Mana'iyya seems to be used in southern Wadi ‘Araba to refer to sites with copper slag mounds (see

⁶ It is interesting to note, however, that U. Avner and Magness (1998: 57) published two middle Islamic-period radiocarbon dates (nos. 21–22) from Be’er Ora. The bulk of the smelting activity at the site is, nonetheless, early Islamic.

⁷ It is important to note, however, that this is not the wadi recorded by the Southeast ‘Araba Archaeological Survey (SAAS) as Wadi al-Nukhayla. Their Wadi al-Nukhayla is c.25 km north of ours, near Jibal Umm Nukhayla, not far to the south of Wadi Gharandal (Smith, 2014: figs. 4.2, 4.46). There are, in fact, dozens of wadis bearing this name in Jordan.

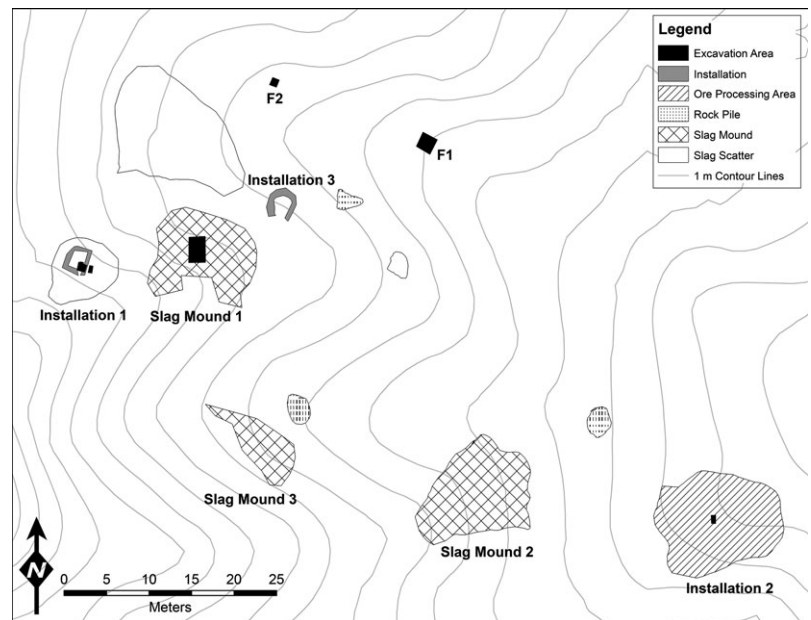


FIGURE 5 A plan of features at Khirbat al-Mana'iyya (map: I.W.N. Jones; data: M. Vincent)

Ben-Yosef, 2016: 171),⁸ which are the most obvious feature of Khirbat al-Mana'iyya.

Prior to Ben-Yosef (2012), Khirbat al-Mana'iyya was briefly mentioned by Weisgerber (2006: 25), who seems to have visited the site and correctly dated it to the early Islamic period, although he did not publish a description.⁹ The site is also marked on the geology map for the Wadi Rahma region as an 'ancient smelting site', but the associated publication does not include a description of the site, nor is an attempt made to date it (Ibrahim K.M.d.K., 1989; with a brief discussion in 1991: 107). The site was not found by the Southeast 'Araba Archaeological Survey (SAAS), as it falls outside the areas they intensively surveyed (Smith, 2014). Ben-Yosef (2012), therefore, was the first to publish a detailed description. Based on the solid slag cakes visible on the surface of the site, he suggested that the site should be dated to the Iron Age II or later (Ben-Yosef, 2012: 68), and discussed it as an Iron Age

site, a claim that is retracted here. Reconnaissance in 2012 quickly revealed that these were in fact fragments of early Islamic-period ring slags, and additional evidence from the excavations—discussed below—confirms this date.

2 | THE 2012 EXCAVATIONS

The 2012 excavation season was aimed at understanding a range of metallurgical activities at the site and consisted of several small probes in five areas: a slag mound, a building, an ore crushing or storage installation, and two possible furnaces (Fig. 5). Due to the small area excavated, the relatively shallow nature of many of the deposits, and the lack of diagnostic artefacts, many of our conclusions about the function of the excavated features remain tentative. The data collected, including samples for radiocarbon dating reported here, however, allow for some conclusions about the nature of early Islamic copper production to be reached.

2.1 | Slag Mound 1

The largest area excavated was Square B, a 2 x 3 m probe in Slag Mound 1 (Fig. 6a; SM1). This area was chosen for excavation because of the presence of a semi-circular feature (L. 003) visible on the surface of SM1. On excavation, this was revealed to be a semi-circular, five-course wall built of slag (Fig. 6b). A straight wall built of small to medium stones and slag pieces (L. 007) was also found at the southern end of the square. The exact purpose of these features is unclear. Structures built of slag have been found at other smelting sites in the southern 'Araba, with the

⁸ Al-Mana'iyya is a diminutive derived from *mana'a*, (Ar. for 'security' or 'immunity'). While this is an accurate description of Arabah Expedition Site 34, Glueck's (1935: 43, fig. 19) "Kh. Mene'iyyeh" (see also Ben-Yosef, 2016), Khirbat al-Mana'iyya is not a very defensible site, suggesting that the toponym has instead been applied because of the site's large slag mounds. It is, nonetheless, possible that the toponym is a reference to the site being 'secured' or guarded in some way.

⁹ The sole published reference to this visit is also rather confusing. Weisgerber (2006: 25) refers to early Islamic-period slag 'identified by the author on the eastern side of the Arabah north of Feinan'. It seems that this is an error, and 'Feinan' should, in fact, read 'Aqaba.' The site in question, based on a photograph generously sent to IWNJ by Dr Ricardo Eichmann, is actually quite likely to be Khirbat al-Mana'iyya, although it is perhaps also possible that Weisgerber identified a second early Islamic smelting site in south-eastern 'Araba. We are indebted to Dr Ricardo Eichmann, Ingolf Löffler, and Dr Andreas Hauptmann for their assistance in clarifying this issue.

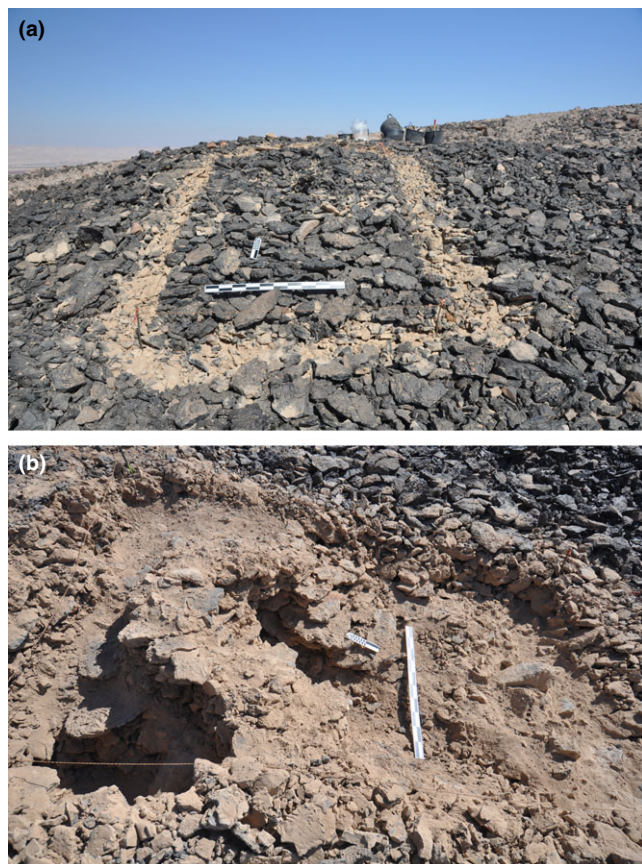


FIGURE 6 Square B in Slag Mound 1: (a) a view of the square prior to excavation; (b) L. 003, a circular feature built of ring slags, during excavation (photos: T.E. Levy) [Colour figure can be viewed at wileyonlinelibrary.com]

best-known example being the slag-built *musalla* at Be'er Ora (Rothenberg, 1988; Sharon, Avner, & Nahlieli, 1996). Features like L. 003 and 007 are also known at Be'er Ora but are currently unpublished. Given the small size of the probe, we were unable to verify that these features form a single structure, but it is possible that the function of these two walls was simply to contain material being dumped into the slag mound. Finds from Square B consisted primarily of medium to large pieces of slag, as well as some tuyere and furnace fragments (Fig. 7). A layer of relatively large ring slag fragments (L. 006) was found beneath L. 003, while the southern portion of the square, near L. 007, contained more small fragments of slag than the northern portion, as well as charcoal fragments.

2.2 | Installation 1

Installation 1 is a small ($c.2 \times 2$ m), square structure 8 m to the west of SM1, with walls preserved from one to five courses (Fig. 8). Two 1×1 m probes were opened in this area in an attempt to clarify the purpose of the installation: Square C4, inside the structure, and Square C5, outside. Deposits in both squares consisted only of a shallow, ashy

layer before bedrock was reached. Finds were extremely rare, limited to a single hammer stone and a small amount of charcoal. The plan of Installation 1 is typical of the 'modular' architecture of early Islamic sites in 'peripheral regions' (Whitcomb, 2006b: 27), and similar structures are known in southern 'Araba, for example at Be'er Ora (Yisrael, 2002: 126, fig. 163) and Eilat (Rapuano, 2013: 130, plan 1), and in the southern Jordanian Hisma in Wadi Shira (al-Bqa'in, Corbett, & Khamis, 2015: 96–106). At these sites, modular rooms are found both individually and as part of linear units, but none of these larger, linear complexes were found at Khirbat al-Mana'iyya. Haiman (1995: 41), U. Avner and Magness (1998: 40), Magness (2004: 20), and Whitcomb (2006b: 35) suggest an association between this type of settlement complex and sedentarisation of Bedouin in the eighth and ninth centuries, and the presence of one of these buildings at Khirbat al-Mana'iyya might suggest an association between the workforce there and this phenomenon.

2.3 | Installation 2

Installation 2 is a large ($c.12$ m in diameter) ore crushing or storage area located at the higher elevations of the eastern end of the site. Surface finds included many small pieces of copper ore, and a 1×0.5 m probe was excavated in order to recover larger pieces of ore for laboratory analysis. Unfortunately, none was recovered from this probe. Finds from L. 001 were limited primarily to small ore pieces similar to those found on the surface, while little was found in L. 002 beyond a hammer stone and decomposed granite. Below L. 002 the excavations reached bedrock.

2.4 | Furnace Probes 1 and 2

Furnace Probes 1 and 2 (F1 and F2) were not separate furnaces, but rather two 1×1 m probes in the northern area of the site. In both probes, a layer of ash and burnt rock was found 1–2 cm below the topsoil, indicating a high-temperature fire and, probably, the presence of a furnace. This is also suggested by the presence of furnace fragments, which were found in F2 but not in F1. Apart from furnace fragments, stone, and several charcoal fragments, the probes in F1 and F2 yielded few finds.

3 | CERAMICS

As with many other smelting camps in southern 'Araba, ceramics are uncommon at Khirbat al-Mana'iyya. Very few sherds were found during the 2012 season, and the majority of these—including all rim sherds—came from the

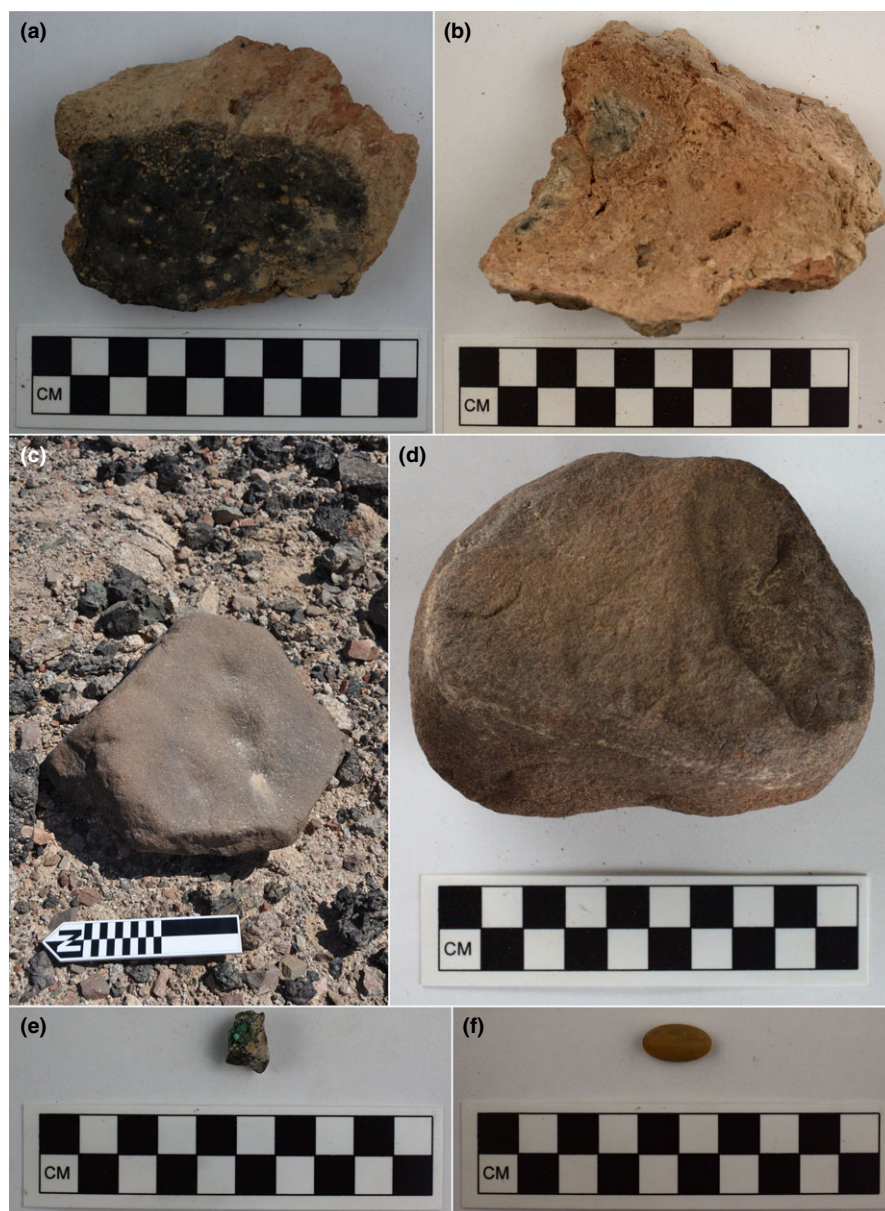


FIGURE 7 Artefacts from Khirbat al-Mana'iyya: (a) partially slagged tuyere, SM1, L. 001; (b) furnace fragment, SM1, surface collection; (c) anvil, surface collection; (d) hammer stone, surface collection; (e) copper ore, Installation 2, L. 002; (f) bead, surface collection (photos: L. Trujillo, except (c), by T.E. Levy) [Colour figure can be viewed at wileyonlinelibrary.com]

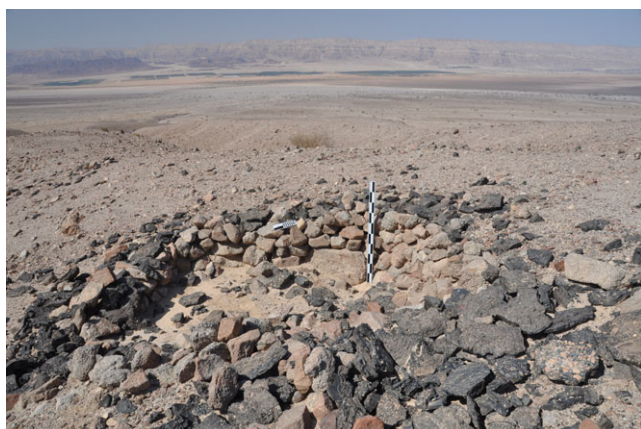


FIGURE 8 Installation 1, facing west. South-western Wadi 'Araba is visible in the background, including the Timna Valley, in the upper left (photo: T.E. Levy) [Colour figure can be viewed at wileyonlinelibrary.com]

surface of Slag Mounds 1 and 2. The diagnostic sherds collected in 2012 belong to two vessels, although body sherds of other vessels are present. The vessels for which diagnostic sherds were recovered are discussed in detail below. Both represent forms that emerge in the final quarter of the early Islamic I and are typical of the first half of the early Islamic II in southern 'Araba.

One of these, Reg. 44667 (Fig. 9/1), is a white-slipped bowl with a squared rim recalling Phocaeen Red Slip 3 and related to Late Roman red-slipped wares (e.g. Egyptian Red Slip A, Form J; on these wares, see Hayes, 1972). The fabric is reddish and well fired, and tempered primarily with coarse sand. Some mica flecks are visible on the surface, as well as a very few small vegetal voids. The form and fabric of this bowl belong to Whitcomb's (1989) Mahesh Ware, which first appears *c.* AD 750 and is

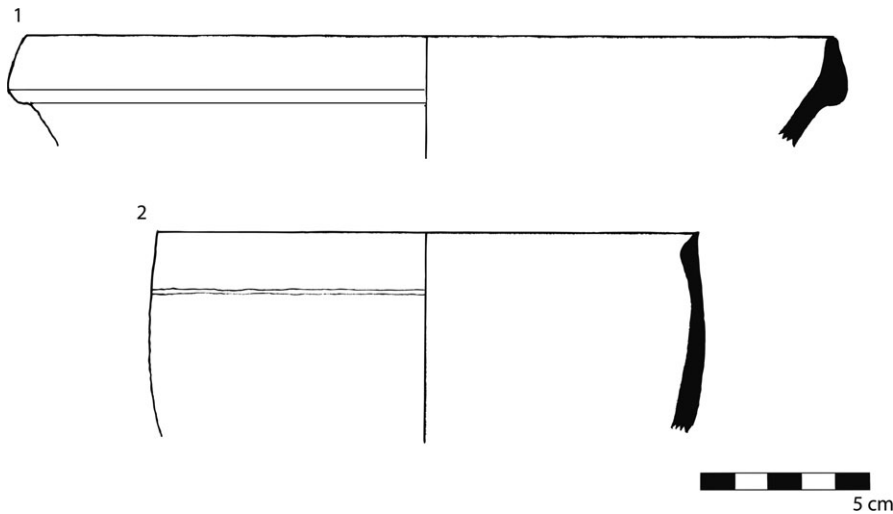


FIGURE 9 Diagnostic pottery from Khirbat al-Mana'iyya (illustrations: I.W.N. Jones)

especially common in the first half of the early Islamic II. Similar bowls are found at Ayla/Aqaba (early 'Abbasid, i.e. AD 750–900—Whitcomb, 1989: 280, fig. 3b), Eilat (early 'Abbasid/ninth century—Rapuano, 2013: 146, fig. 19.3,5), and 'En 'Avrona (early Islamic—Porath, 2016: 24*, fig. 26.6–7,10–11,13). A similar form is also present in the middle Islamic levels at Tell Jemmeh, but the parallels provided suggest a late Byzantine–early Islamic date (Schaefer, 1989: 39, fig. 4.2).

The other, Reg. 44586 (Fig. 9/2), is a simple, small bevel-rim bowl with an exterior cream slip. The fabric is reddish and well fired and tempered primarily with coarse sand. Some mica flecks are visible on the surface, and small grogs or argillaceous inclusions are visible in the breaks. This form is much more common than the previous example but should also be considered Mahesh Ware and dated similarly. Parallels are found at Ayla/Aqaba (early 'Abbasid—Whitcomb, 1989: 281, fig. 4m–o), Eilat (early 'Abbasid/ninth century—Avner R., 1998: 30*, fig. 12.7; Rapuano, 2013: 146, fig. 19.10–12), 'En 'Avrona (early Islamic—Porath, 2016: 21*, fig. 25.4–5), Be'er Ora (south-east) (early Islamic—Yisrael, 2002: 127, fig. 165.2), Sede Boqer (early Arab—Nevo, 1991: 154, pl. 6.17–18), and in the survey assemblage from Khirbat Faynan (early Islamic—Adams, Johnson, & Tomber, 2007: 783–784, no. 579). This form is also very similar to Magness's (1993: 194, 196) Fine Byzantine Ware Bowl 1E, dated to the eighth–ninth century AD, and to the widely known early Islamic wares of central and northern Jordan found, for example, at al-Muwaqqar ('Abbasid—Najjar, 1989: 313, fig. 5.10), Tall Hisban (Umayyad—Sauer, 1973: 41, fig. 3.123; early Islamic I—Walker, 2012: 510, fig. 4.1.20), and Khirbat al-Mafjar (AD 750–800—Whitcomb, 1988: 55, fig. 1D), among others, although this last group is often painted. A similar small bowl was found during Rothenberg's (1972: 222, fig. 72.5) excavations at Be'er Ora, but dated, along with the rest of the pottery from the site, to the second

century AD. It is likely that this should, in fact, also be dated to the late eighth–ninth century.

4 | DATING

The limited ceramic material from Khirbat al-Mana'iyya suggests a date in the late eighth–ninth century, or the late early Islamic I to the early Islamic II. Because of the small number of datable artefacts, we also processed a radiocarbon date from a fragment of acacia charcoal from F2 L. 001 in order better to understand the chronology of the site. The calibrated date places the use of the furnace between AD 654 and 758.¹⁰

There is not, necessarily, a contradiction between these dates. The lack of stratigraphy in F2 makes it impossible to say whether this sample dates the beginning, end, or middle of production in F2. Likewise, it is impossible to rule out error from potential inbuilt age bias in the wood (the 'old-wood effect'). The charcoal from Khirbat al-Mana'iyya, including the material sampled for radiocarbon, is extremely fragmentary, so it was not possible to find charcoal from a secure context containing bark and the outermost (most recent) tree-rings, or from small-diameter branches, which would minimise inbuilt age bias and give a date close to the tree's harvesting. Acacia, which comprises the majority of the charcoal recovered from Khirbat al-Mana'iyya, can in fact grow for several centuries (see Andersen & Krzywinski, 2007). Hauptmann (2007: 155), for example, notes that the exploitation of older trees might have skewed the radiocarbon dates from a Roman period slag mound in Faynan by at least a century, and Ben-Yosef et al. (2012: 63) found an offset of up to 160 years

¹⁰AA-104585, 1331 ± 28 BP, 654–758 cal. AD (1σ), 650–766 cal. AD (2σ). Calibrated with IntCal13 (Reimer et al., 2013) using OxCal 4.2 (Bronk Ramsey, 2009).

between ^{14}C dates on acacia wood and short-lived seeds at Timna. There is also evidence from charcoal analysis that the Khirbat al-Mana'iyya acacia samples were already dead when harvested (see below), creating an even greater potential offset. The ^{14}C sample date can therefore be considered only as a *terminus post quem* for smelting activity.

More generally, the date of the earliest phase of the industry is still an open question. Again, reference to the western Arabian mining industry is informative. Heck (1999, 2003) argues that the Arabian mining industry was already quite large by the seventh century, and played a pivotal role in the emergence of the earliest Islamic state. Power (2012), in a recent re-evaluation of this evidence, suggests that the situation might not be so clear. Instead, he suggests a possible relationship between the mines and the 'Abbasid Darb Zubayda—the route from Baghdad to Mecca—noting that 'the steady flow of gold to the mint of Baghdad should not be ignored' when considering the development of this route (Power, 2012: 124). This is interesting in light of the evidence from al-Nuqra, which, although limited, points to mineral exploitation, including copper, primarily during the 'Abbasid period (de Jesus et al., 1982: 63; see discussion in Power, 2012: 123). Likewise, al-Rabadha—a large town situated roughly halfway between the mines at al-Nuqra and Mahd al-Dhahab on the Darb Zubayda—although occupied at least as early as the seventh century AD, was economically important primarily in the eighth–tenth century, probably because of its association with the mines (al-Rashid, 1986: 14). For Wadi 'Araba, it has been the case for several decades that ceramics and other diagnostic artefacts from early Islamic sites tend to date to the eighth–ninth century, while radiocarbon dates from the same sites give a range between the seventh and eleventh centuries (Avner U. & Magness, 1998: 51). Unfortunately, Nol's (2015: 53–55) recent review of this evidence shows that the situation remains the same, and the evidence from our investigation of Khirbat al-Mana'iyya follows the same pattern. There are three short plateaus (on the term, see Guilderson, Reimer, & Brown, 2005) in the radiocarbon calibration curve that may contribute to this problem, covering the mid-seventh to mid-eighth century, the ninth century, and much of the tenth century. The radiocarbon sample from Khirbat al-Mana'iyya falls into the first plateau, but this early date may also be related to the use of deadwood for charcoal (discussed below).

One potential exception to the pattern discussed above is worth noting. Damgaard (2009: 89) argues that mining occurred in southern 'Araba as early as the seventh century, but that during this early phase, ore was transported to and smelted in the city of Ayla. He argues that evidence from the excavations of Ayla's congregational mosque supports this view, as pieces of copper slag were found in the

pre-construction phases (Damgaard, 2009: 89). In this view, then, smelting begins outside Ayla only in the mid-eighth century, but mining in southern 'Araba occurred during the seventh or early eighth century as well. As Nol (2015: 65, n. 4) has recently noted, however, it is difficult to evaluate this evidence, as the excavations have not been fully published, and the context and quantity of the slag itself is unclear. Beyond this, Whitcomb (2006a: 241) refers to the same objects as 'cut fragments of copper, wastage of copper object production within the city', suggesting that they may not be pieces of slag at all. It is likelier, instead, that this is either debris from copper object production or from recycling, as Ponting (2008: 55, 58) found to be the case for an eleventh-century hoard from Tiberias (and see additional examples in Jones, Levy, & Najjar, 2012: 93–94). When published, it is possible that these data may force a re-evaluation of the beginnings of the early Islamic southern 'Araba copper industry. This, however, does not have any direct bearing on the dating of Khirbat al-Mana'iyya.

Given our current knowledge of early Islamic ceramic typologies in southern 'Araba, and Power's (2012) re-evaluation of the western Arabian evidence, Nol's (2015: 53) decision to accept an eighth–ninth-century date for the early Islamic settlements of southern 'Araba is sensible. If the premise that these industrial settlements are connected to the development of the hajj routes is accepted, however, Petersen's (1994: 48) claim that 'the Syrian pilgrimage route benefitted under the Umayyad dynasty based in Damascus, whilst the Iraqi routes [primarily Darb Zubayda, connecting Baghdad to the Hijaz] were developed during the Abbasid dynasty based in Baghdad' should also be considered. With this in mind, an earlier initial development in association with the development of the hajj route from Damascus, in the late seventh–early eighth century, might be proposed for the southern 'Araba system, which was maintained and perhaps expanded into the ninth century at least. While comparison to other sites suggests that Khirbat al-Mana'iyya probably dates to the eighth–ninth century, it is presently safest to suggest a seventh–ninth-century date. Refining this date will require more research, both at Khirbat al-Mana'iyya and in southern 'Araba more generally.

5 | GEOLOGICAL AND ENVIRONMENTAL CONSIDERATIONS

Copper mineralisation in southern 'Araba is concentrated primarily in the south-west, in the region of Timna and nearby Wadi 'Amram. There, copper is found in the sandstone of the Avrona and Amir Formations and the dolomite

and shales of the Timna Formation (Hauptmann, 2007: 66–67; Shlomovitch et al., 1999: 196–197). These have equivalents in the Faynan region of north-eastern 'Araba, c.105 km north-east of Timna, due to the fact that these deposits formed together and were later separated by tectonic movement (Hauptmann, 2007: 68). As a result of these geological processes, substantial copper deposits tend to be limited to north-east and south-west 'Araba. Copper-smelting sites generally tend to be found in close proximity to copper deposits, and archaeological survey in these regions confirms that this is the case.¹¹ While numerous copper smelting sites are known in Faynan (see Barker, Gilbertson, & Mattingly, 2007; Hauptmann, 2007; Levy, Najjar, & Ben-Yosef, 2014)—although none of these, at present, can be dated to the early Islamic period (Jones et al., 2012: 70; 2014: 182–185)—very few, small smelting sites are known in north-west 'Araba, for instance, 'En Yahav (Yekutieli et al., 2005). Likewise, many smelting sites are found in south-west 'Araba (see Avner & Magness, 1998: 40–44; Rothenberg, 1972; 1999), but relatively few have been found in south-east 'Araba (other than Khirbat al-Mana'iyya; see Smith, 2014: 217–219).

For the early Islamic period, in particular, the largest dated copper mines in southern 'Araba are those in Wadi 'Amram (Avner U. et al., in press; Willies, 1990, 1991), c.7 km south-west of Be'er Ora and 20 km south-west of Khirbat al-Mana'iyya. Smaller mines of the same period are also known in Nahal Rehav'am, which is c.15–20 km south of Wadi 'Amram, between Eilat and Taba (Shmueli, Lender, & Lifshits, 2013), and to the west and south-west of Taba (Avner U. & Magness, 1998: 40). These smaller mines are likely to have been sources for smelting camps closer to Ayla. Based on proximity, the Timna Valley proper, c.15 km to the west, seems the likeliest source of ore for Khirbat al-Mana'iyya, although the large Wadi 'Amram mines are also a possibility.

In contrast, geological mapping across Wadi 'Araba to the east of Timna found only 'traces of copper and manganese' (Ibrahim K.M.d.K., 1991: 102). There is potential copper mineralisation c.12 km to the east of Khirbat al-Mana'iyya, near Jabal Abu Saq'a and Jabal al-Dahmi (1991: 102), but based on presently available evidence, it is not clear that the area was ever mined. Fifteen kilometres to the north, in Wadi al-Khubat, there is another source of copper with some evidence of exploitation (see discussion in Ben-Yosef, 2012: 69, n. 8; Haviv, 2000: 219). Neither of these sources, however, is particularly substantial, and it

is worth noting that none of them is much closer to Khirbat al-Mana'iyya than the sources in south-west 'Araba. While it is possible that they were exploited during the early Islamic period, it is very unlikely that they represent the primary ore sources for Khirbat al-Mana'iyya. This raises the question of why this location, not particularly close to any ore source, was chosen for a copper-smelting site.

Ben-Yosef (2012: 69–72) speculated that the location of Khirbat al-Mana'iyya was attractive primarily due to its proximity to two resources uncommon in south-west 'Araba, and particularly uncommon in the Timna Valley: water and wood (Fig. 10). A similar argument has been put forward to explain the location of Early Bronze Age 'En Yahav in north-west 'Araba, which is c.20 km from its likely ore sources (Yekutieli et al., 2005: 19). A nearby source of water has obvious benefits, and proximity to wood resources may have been more important than proximity to ore sources. For much ancient copper smelting, more wood than ore would have been required, which would have made transporting the ore to the fuel source an efficient choice (Ben-Yosef, 2012: 71; Hauptmann, 2007: 52–53). Published charcoal assemblages for early Islamic



FIGURE 10 The location of a potential water source south of Khirbat al-Mana'iyya. Note also the acacia trees dotting Wadi al-Nukhayla (map: IWNJ, base map: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community) [Colour figure can be viewed at wileyonlinelibrary.com]

¹¹The early copper metallurgy of the Chalcolithic period represents the major exception to this rule, with smelting sites located as far as 100 km from probable ore sources (see e.g. Shalev & Northover, 1987: 362). The socio-political factors behind this long-distance transport of ore are discussed by Levy (1995), but do not affect our broader claim here.

smelting sites in southern 'Araba are uncommon, but ten charcoal samples were collected during excavations at Be'er Ora. Of these, six were from *Acacia* species, two from *Tamarix aphylla*, and two from *Suaeda monoica* (Avner U. & Magness, 1998: 43). While this is a charcoal assemblage with a very small sample size, it nonetheless suggests that acacia was a key source of charcoal for early Islamic copper smelters in southern 'Araba. *Acacia* is fairly common around the alluvial fans of Wadi al-Nukhayla, and we expected to find that the majority of smelting fuel used at Khirbat al-Mana'iyya was acacia charcoal.

Identification of 266 charcoal fragments from four excavation loci from the site suggests that this is the case. Of the 266 fragments in the assemblage, 198 fragments (74%) could be identified to one of five taxa (Table 1). *Acacia* (*Acacia* sp.) is by far the most abundant taxon, comprising

TABLE 1 Absolute fragment counts (Af) and percentage abundance (%f) of wood charcoal taxa sampled from Khirbat al-Mana'iyya. The percent ubiquity of specific taxa in the sampled contexts was not calculated because of the relatively small number of samples available from each excavated area and the site as a whole

Taxon	Af	%f
<i>Acacia</i> sp.	172	87
Amaranthaceae-Chenopodioideae	13	7
Fabaceae	5	3
<i>Haloxylon persicum</i>	3	2
<i>Retama raetam</i>	5	3
Indeterminate	68	
Totals	266	100

87% of the identified fragments, and is present in all sampled loci. The aliform-tangentially confluent parenchyma bands, multi-seriate rays, and thick-walled fibres (Fig. 11a–d) observed indicate that the wood is most likely *Acacia tortilis* (Forssk.) Hayne (Fahn, Werker, & Baas, 1986). The remaining 13% of the identified charcoal assemblage consists of the Chenopodioideae sub-family of Amaranthaceae, some of which may be identified as white saxaul (*Haloxylon persicum* Bunge) (Fig. 11e); small fragments of white broom (*Retama raetam* [Forsk.] Webb); and other small legume fragments (family Fabaceae), which are too small, too poorly preserved, or lacking sufficient diagnostic features to be identified to genus or species.

Haloxylon persicum (along with several other species in the Chenopodioideae sub-family) and *Retama raetam* are shrubs found in hot, arid desert and steppe environments and are capable of growing on sandy wadis, alluvial fans, and flood plains, and desert pavement environments, like those found near Khirbat al-Mana'iyya. These results fit the general pattern of fuel provisioning for copper smelting in southern 'Araba, and suggest that Khirbat al-Mana'iyya's location near these resources made it more desirable for establishing a smelting camp than the Timna Valley to the west.

All three species (*Haloxylon persicum*, *Acacia tortilis*, and *Retama raetam*) are dense woods that produce considerable heat when burnt (Engel & Frey, 1996), which would have made them attractive fuel sources for smelting operations requiring high temperatures. Because the samples have high fragmentation and poor preservation, it was not possible to estimate the approximate diameter and size of the original timber when it was procured. Examination of

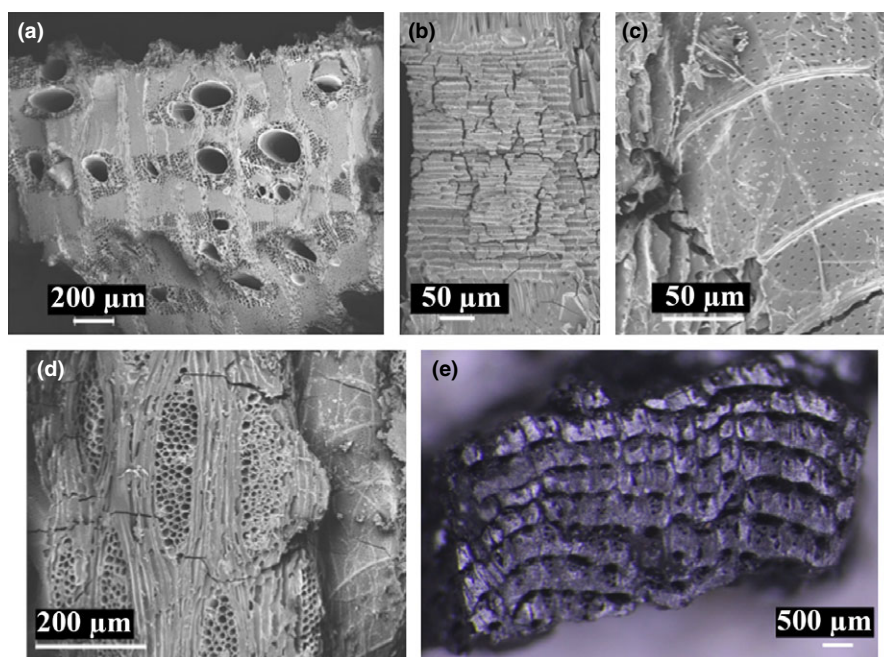


FIGURE 11 SEM microphotographs of wood charcoal specimens from Khirbat al-Mana'iyya, showing *Acacia* sp.: (a) transverse; (b) radial; (c–d) tangential sections, in which there are fungal hyphae present on vessel walls, indicating burning of deadwood; (e) light microscope photograph of *Haloxylon persicum* transverse section (photos: B. Lorentzen) [Colour figure can be viewed at wileyonlinelibrary.com]

acacia charcoal under a scanning electron microscope (SEM) revealed the presence of fungal hyphae in the vessels, which indicates a collection of dry deadwood (Asouti & Austin, 2005; Moskal-del Hoyo, Wachowiak, & Blanchette, 2010). Deadwood is an attractive fuel source because it is easier to collect and carry and does not require additional time to dry out before it is burnt. Use of acacia deadwood may also suggest some degree of 'tending' to local acacia in 'Araba by preferentially trimming dead branches and stems, in order to renew the tree as a source of additional fuel or fodder. Bedouin in the Sinai Peninsula use similar tending practices on modern acacia trees (Andersen et al., 2014), and Ben-Yosef and Levy (2014) have proposed that reverence for the acacia tree by pastoral nomads in the southern Levant affected fuel selection at smelting sites in the Faynan region during the Iron Age.

6 | PRELIMINARY X-RAY FLUORESCENCE (XRF) ANALYSIS

As part of our pilot project, we conducted a preliminary chemical study of the slag from Khirbat al-Mana'iyya using a Bruker Tracer III-V+ portable X-ray fluorescence (pXRF) spectrometer. Five 300-second surface readings of each sample were taken using instrument settings for analysing heavier elements (40Kv, 15µA, no vacuum, green filter [0.006" Cu, 0.001" Ti, 0.012" Al]). These were then calibrated using data collected by Ben-Yosef (2010) for Iron Age slag from the Faynan region. The means of these calibrated readings are presented here in wt-% (Table 2). Five slag samples from Khirbat al-Mana'iyya were analysed, as well as four middle Islamic period slag samples from the Faynan region (two from Khirbat Faynan and two from Khirbat Nuqayb al-Asaymir), for comparison.

Several caveats about these data must be kept in mind. First, the readings were obtained from the surface of the slag, rather than slag crushed into a powder. Slag is a heterogeneous material, and readings can vary substantially across the surface of a single sample. While five surface readings were taken from each sample in order to address this problem, this variation has led to rather large standard deviations for many of the elements of interest here, in particular Ca, Fe, Cu, and, for some samples, Mn. Second, these readings were taken using instrument settings primarily appropriate for heavier elements. As such, the wt-% of the lighter elements—K, Ca, and Ba—is probably under-represented. Because it is very light, Si, a major component of slag, is not included in the calibration at all. Third, the fact that the calibration was developed for Iron Age slag from Faynan has probably introduced some error, as the composition of early and middle Islamic-period slag is rather different. The data presented here must, therefore, be

considered preliminary, rather than definitive, and further chemical analysis of the slag from Khirbat al-Mana'iyya is planned for 2018.

Nonetheless, several interesting points emerge from this analysis. Although the wt-% of Ca is probably inaccurate, the samples from Khirbat al-Mana'iyya are, with the exception of Sample 3, within the range published by Bachmann (1980: 115, table 7) for Be'er Ora, and significantly higher than the Iron Age samples from Timna analysed by Ben-Yosef (2010: 855, table 8.7). As expected, much more Mn is present in the samples from Faynan, as the ores exploited by the middle Islamic-period miners 'are intensively intergrown with oxidic manganese ores' (Hauptmann, 2007: 70). The wt-% of Fe in the samples from Khirbat al-Mana'iyya is somewhat low compared to Ben-Yosef's (2010: 855, table 8.7) Iron Age Timna samples, but within the range for the Be'er Ora samples (Bachmann, 1980: 115, table 7), although the very large standard deviations must be kept in mind. The high wt-% of Fe in the middle Islamic-period slag samples from the Faynan region, particularly Samples 6 and 8, is also noteworthy in light of the very low Fe content in Iron Age (Ben-Yosef, 2010: 851–855, table 8.7) and Roman (Hauptmann, 2007: 350–351, table A.4) Faynan slag, but is comparable to middle Islamic slag from the same sites analysed by Hauptmann (2007: 351, table A.4). This reflects engagement with Fe-rich copper ore sources (see Hauptmann, 2007: 71) in the middle Islamic period and/or the use of iron oxides as flux, a practice that might be related to the adventitious production of iron identified at Khirbat Nuqayb al-Asaymir (Hauptmann, 2007: 96, 126–127; Jones, 2016: 121).

7 | IMPLICATIONS

7.1 | Settlement patterns in southern 'Araba

Our pilot season at Khirbat al-Mana'iyya has important implications for the study of the early Islamic period in southern 'Araba. The location of the site should perhaps not be surprising, as Khirbat al-Mana'iyya is within 15 km of both the Timna Valley and the large smelting camp at Be'er Ora. Its presence in south-east 'Araba, however, contradicts previous views of settlement patterns in southern 'Araba. The preliminary report of the Southeast 'Araba Archaeological Survey (SAAS), for example, reported a 'virtual absence of Early and Late Islamic period sites' other than the major settlement at Ayla (Smith, Stevens, & Niemi, 1997: 67). While fourteen sites definitively dating to the early Islamic period are included in the final report of the survey (Smith, 2014: 160–161), the pattern that emerges seems to support the interpretations of the preliminary report. Many of the sites are described as pot-drops or ephemeral reoccupations of earlier sites, and many are

TABLE 2 Elemental compositions (in wt-%) of slag samples from Khirbat al-Mana'iyya (KM), Khirbat Faynan (KF), and Khirbat Nuqayb al-Asaymir (KNA) based on averaged surface readings taken using a portable X-ray fluorescence spectrometer (pXRF). Column “n” lists the number of readings taken for each sample. The final row lists the averages of all readings taken on the five samples from Khirbat al-Mana'iyya

Sample	Context	n	Period	Type	K	Ca	Ba	Ti	Mn	Fe	Ni	Cu	Zn	Pb
1	KM, SM1, Sq. B, B. 1, R. 35514	5	Early Islamic	Cu slag (slagged furnace fragment)	2.54 ± 0.16	6.43 ± 0.16	0.1 ± 0.24	0.11 ± 0.003	5.44 ± 1.4	14.39 ± 10.71	0.06 ± 0.01	0.89 ± 0.35	0.1 ± 0.04	0.01 ± 0.05
2	KM, SM1, Sq. B, B. 119, R. 35486	5	Early Islamic	Cu slag	2.53 ± 0.16	11.02 ± 3.01	0.02 ± 0.24	0.11 ± 0.004	6.82 ± 1.79	19.7 ± 11.84	0.05 ± 0.01	2.41 ± 2.81	0.18 ± 0.05	0.12 ± 0.05
3	KM, SM1, Sq. B, B. 33, R. 35519	5	Early Islamic	Cu slag (slagged tuyere)	2.52 ± 0.15	3.96 ± 1.58	0.05 ± 0.19	0.11 ± 0.003	4.79 ± 1.44	10.06 ± 13.88	0.06 ± 0.03	4.49 ± 6.91	0.35 ± 0.14	0.15 ± 0.07
4	KM, SM1, Sq. B, B. 36	5	Early Islamic	Cu slag	2.61 ± 0.14	11.62 ± 4.78	0.42 ± 0.28	0.12 ± 0.004	7 ± 1.2	18.18 ± 6.53	0.05 ± 0.01	1.55 ± 0.65	0.15 ± 0.04	0.07 ± 0.02
5	KM, Surface, R. 35523	5	Early Islamic	Cu slag	2.6 ± 0.17	9.59 ± 2.93	0.11 ± 0.19	0.11 ± 0.003	6.72 ± 1.72	15.58 ± 9.19	0.05 ± 0.01	1.88 ± 1.94	0.13 ± 0.04	0.07 ± 0.03
6	KF, Area 15, L. 5, R. 34015	5	Middle Islamic	Cu slag	2.88 ± 0.13	9.02 ± 1.55	1.36 ± 0.2	0.13 ± 0.003	21.84 ± 1.95	40.05 ± 4.53	0.05 ± 0.004	0.97 ± 0.37	0.05 ± 0.01	0.04 ± 0.01
7	KF, Area 15, L. 10, R. 33771	5	Middle Islamic	Cu slag	2.73 ± 0.12	6.67 ± 1.56	1.11 ± 0.21	0.13 ± 0.003	14.94 ± 5.39	21.76 ± 10.43	0.03 ± 0.01	0.64 ± 0.25	0.04 ± 0.02	0.01 ± 0.01
8	KNA, Area X, L. 163, R. 50143	5	Middle Islamic	Cu slag	2.76 ± 0.1	12.86 ± 6.14	1.13 ± 0.68	0.13 ± 0.01	21.83 ± 2.18	36.44 ± 2.72	0.04 ± 0.003	3.02 ± 2.21	0.09 ± 0.04	0.04 ± 0.01
9	KNA, Area X, L. 167, R. 50147	5	Middle Islamic	Cu slag	2.98 ± 0.08	9.65 ± 1.19	0.83 ± 0.13	0.12 ± 0.002	17.99 ± 2.65	6.7 ± 1.75	0.07 ± 0.001	0.69 ± 0.31	0.04 ± 0.02	0.05 ± 0.03
KM, averages of all samples		25			2.56 ± 0.15	8.52 ± 4.31	0.11 ± 0.27	0.11 ± 0.004	6.16 ± 1.66	15.58 ± 10.36	0.05 ± 0.02	2.42 ± 3.4	0.18 ± 0.11	0.09 ± 0.05

close to or within the modern city of 'Aqaba, suggesting an association with Ayla. Khirbat al-Mana'iyya is surprising because it does not conform to this pattern. It is over 25 km north-east of the Islamic period city of Ayla, and was newly established in the early Islamic period. Instead, it is a type of site that seems typical of south-west 'Araba, where industrial settlement in the eighth–ninth century was quite common (Avner & Magness, 1998). This raises the question of how secure our knowledge of settlement in south-east 'Araba actually is.

As Nol (2015: 53) has recently argued, the misdating of early Islamic sites to the Byzantine period—a phenomenon that scholars have noted for decades (Avner U. & Magness, 1998: 52; Whitcomb, 1992)—remains a problem in southern 'Araba, and it is likely that many sites identified as Byzantine in surveys should in fact be placed in the early Islamic period. Indeed, this is particularly likely given that 'all published sites excavated in the Arava since the 1990s have been dated to the Early Islamic period, even when identified as Byzantine in earlier surveys' (Nol, 2015: 53 [our emphasis]). Khirbat al-Mana'iyya, however, brings up a second issue. Artefacts that would commonly be used for dating on a survey—particularly ceramics—are very uncommon at the site, even in excavated contexts. Although several features of the ring slag found on its surface—notably the central, cast-in hole and the prominent flow-banding—could be used to date the site, these were initially missed (see Ben-Yosef, 2012), and this dating criterion is relevant only for metallurgical sites. It is likely, given all of this, that the paucity of early Islamic sites in south-east 'Araba is a product of the intensity of research and nature of the sites as much as or even more than it is a product of the actual number of sites.

This is also likely to be the case for the copper industry specifically. Indeed, the SAAS identified several small, undated smelting sites near Khirbat al-Mana'iyya (Smith, 2014: 217–219). None of these sites necessarily dates to the early Islamic period, but this does demonstrate that there are gaps in our understanding of the metallurgical landscape of south-east 'Araba, even at the known sites. Beyond this, Khirbat al-Mana'iyya itself was not recorded by the SAAS. This is understandable, given that the intensity of survey in this portion of the study area was limited by both project resources and the landscape itself (Smith, 2014: 115), but again demonstrates that settlement in this region has not been completely documented. Simply put, there is much scope for future surveys and excavations in south-east 'Araba.

7.2 | The organisation of early Islamic-period copper smelting

Two of the key questions regarding any industry concern its organisation and the motivation for its establishment.

While these questions are rather difficult to answer archaeologically, the spatial organisation of a copper industry can provide insight into its political-economic organisation and rationale. For example, the middle Islamic copper industry in Faynan was organised around only two sites, the largest of which was a village constructed solely for this purpose, indicating a relatively high degree of centralisation, and very likely a state-run industry (Jones et al., 2012: 90). By contrast, the early Islamic-period industry in Oman was organised around a number of small settlements, each with its own house, furnace, roasting installation, and slag mound, indicating that mining in that region was probably less organised, and copper producers more autonomous (Weisgerber, 1987: 158). The southern 'Araba industry suggests a situation somewhere between these two. In southern 'Araba, copper was produced in camps, and it is likely that copper producers lived in some combination of tents and the villages scattered throughout south-western 'Araba, as discussed above (see Fig. 1). These options are by no means mutually exclusive, either, as the village of Eilat "has been suggested as a composite settlement with tents" (Whitcomb, 2006b: 35).

Two of these smelting camps—Be'er Ora and another, which no longer survives, near Umm Rashrash in the modern Israeli city of Eilat (Avner U. & Magness, 1998: 42)—were rather large, but a number of other, smaller camps are also known (U. Avner and Magness [1998: 42] list three; Nol [2015: 57, fig. 3] indicates eight camps, but does not comment on their size; Peters, Tauxe, and Ben-Yosef [in press] have identified two early Islamic-period slag mounds on the base of the hill below Timna Site 34). While Khirbat al-Mana'iyya is definitely larger than any site in the Timna Valley (Ben-Yosef, 2012: 66), its several hundred tons of slag represent a much smaller output than the 5000 tons estimated for Be'er Ora (Avner U. & Magness, 1998: 42), and as such it is a mid-sized camp for the early Islamic period.

This pattern suggests an organisation closer to the one seen in Oman, with entrepreneurs or producers setting up camps, probably organised at least partially along tribal lines. The larger camps at Be'er Ora and Umm Rashrash seem to represent the most successful examples, but Khirbat al-Mana'iyya was certainly more successful than the smaller camps in the Timna Valley.

The destination of this copper is still not entirely certain, but it seems clear that most of it would have been transported through the nearby port of Ayla (see e.g. Avner U. & Magness, 1998; Damgaard, 2009; Jones et al., 2014, in press; Nol, 2015; Whitcomb, 2006a), and from there into the Red Sea and beyond. As Power (2012: 124) has argued for the western Arabian mines, the narrower dating discussed above makes a connection to the rise of the 'Abbasids likely. It is noteworthy here that the 'Abbasid family

lived at the site of Humayma, in southern Jordan, prior to their ascent to power (see Schick, 2007). The nature of this connection, if it existed, is unclear, however, beyond de Jesus et al.'s (1982: 63) assertion that 'the Abbasids were highly committed to the exploitation of copper and gold on the Arabian Shield.' More work remains to be done, but any explanation must take account of the fact that copper mining in southern 'Araba occurred at a much smaller scale than along the Darb Zubayda. Infrastructural improvements like the construction of *qanats* certainly show the investment of state resources in Wadi 'Araba (Avni, 2014: 282–283), but this does not necessarily indicate direct state administration of the hinterland settlements of southern 'Araba. Indeed, if Whitcomb (2006b: 41) is correct that modular village settlement in the region was economically 'necessary and spontaneous' due to a decrease in demand for traditional nomadic products like meat, nomadic groups may have adapted to this economic change by engaging in copper mining, and this may in turn have been encouraged or even supported by the 'Abbasid state. The involvement of nomadic groups in the administration of copper production may also be indicated by the preference for deadwood as a fuel source, as discussed above.

8 | CONCLUSION

Our pilot season of excavations at Khirbat al-Mana'iyya conclusively demonstrates that the site dates to the early Islamic period, making it the first copper smelting site of this period known in south-east 'Araba, with the possible but unlikely exception of Ayla. It is not possible to establish a precise date on the basis of the material presented here, but a date within the range of the seventh–ninth century is certain, and comparison to copper smelting sites in south-west 'Araba and beyond suggests that an eighth–ninth-century date is most likely. The location of the site, nearly 15 km from the nearest substantial source of copper ore, is most likely explained by its proximity to wood and water resources, both of which would have required more effort to transport to the ore sources than vice versa.

While the present understanding of industrial settlement in southern 'Araba is good, Khirbat al-Mana'iyya demonstrates that it is not complete, particularly in the south-east. More importantly, however, our discussion of Khirbat al-Mana'iyya here demonstrates three lacunae in the present state of knowledge of how this system functioned. First, what explains the distinction between the sizes of smelting camps? Does this represent a difference in the quality or quantity of local resources or investment? Or is it perhaps related to temporal factors, such as a gradual concentration of labour at larger, longer-lived camps? Second, what is the relationship between the organisation of industrial

settlements in southern 'Araba and the larger mines in the Hijaz and western Najd? Was the 'Abbasid state directly involved in the administration of mining in both regions or, as we suggest here, were the mines in southern 'Araba the result of state sponsorship rather than direct state control? Third, did all of the mines in southern 'Araba become active at the same time, in the second half of the eighth century, or did some first become active in the late seventh/early eighth century? If so, is this evidence of similar patterns of exploitation of resources near the hajj routes by both the Umayyads and 'Abbasids? While more work remains to be done before answers to these questions can be proposed, our work at Khirbat al-Mana'iyya suggests that excavation at copper-production sites—especially those with few surface finds—can produce important data in the future.

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REFERENCES

- Adams, R., Johnson, E., & Tomber, R. (2007). Bronze Age and Iron Age pottery, and Classical and Islamic pottery catalogue. In G. Barker, D. Gilbertson, & D. Mattingly (Eds.), *Archaeology and desertification: The Wadi Faynan Landscape Survey, southern Jordan*. CD-ROM Supplement. Oxford: Oxbow: 761–810.
- Andersen, G.L., & Krzywinski, K. (2007). Longevity and growth of *Acacia tortilis*; insights from ^{14}C content and anatomy of wood. *BMC Ecology*, 7/4: <https://doi.org/10.1186/1472-6785-7-4>
- Andersen, G.L., Krzywinski, K., Talib, M., Saadallah, A.E.M., Hobbs, J.J., & Pierce, R.H. (2014). Traditional nomadic tending of trees in the Red Sea hills. *Journal of Arid Environments*, 106: 36–44. <https://doi.org/10.1016/j.jaridenv.2014.02.009>
- Asouti, E., & Austin, P. (2005). Reconstructing woodland vegetation and its exploitation by past societies, based on the analysis and interpretation of archaeological wood charcoal macro-remains. *Environmental Archaeology*, 10: 1–18. <https://doi.org/10.1179/env.2005.10.1.1>
- Avner, R. (1998). Elat-Elot—An early Islamic village. *Atiqot*, 36: 21*–39*, 124–125. (In Hebrew with English summary).
- Avner, U. (2014). Egyptian Timna — Reconsidered. In J.M. Tebes (Ed.), *Unearthing the wilderness: Studies on the history and archaeology of the Negev and Edom in the Iron Age*. Leuven: Peeters: 103–162.
- Avner, U., & Magness, J. (1998). Early Islamic settlement in the southern Negev. *Bulletin of the American Schools of Oriental Research*, 310: 39–57.
- Avner, U., Ginat, H., Shalev, S., Shilstine, S., Langford, B., Frumkin, A., ... Cummings, L.S. (In press). Ancient copper mines at Nahal 'Amram, southern Arabah. In E. Ben-Yosef (Ed.), *Mining for ancient copper: Essays in memory of Prof. Beno Rothenberg*. Tel Aviv: Tel Aviv Institute of Archaeology: 146–177.
- Avni, G. (2014). *The Byzantine-Islamic transition in Palestine: An archaeological approach*. Oxford: Oxford University Press.
- Bachmann, H.-G. (1980). Early copper smelting techniques in Sinai and in the Negev as deduced from slag investigations. In P.T. Craddock (Ed.), *Scientific studies in early mining and extractive metallurgy*. London: British Museum. 103–134.
- Barker, G., Gilbertson, D., & Mattingly, D. (Eds.). (2007). *Archaeology and desertification: The Wadi Faynan Landscape Survey, southern Jordan*. Oxford: Oxbow.
- Benvenisti, M. (2000). *Sacred landscape: The buried history of the Holy Land since 1948*, transl. M. Kaufman-Lacusta. Berkeley: University of California Press.
- Ben-Yosef, E. (2010). *Technology and social process: Oscillations in Iron Age copper production and power in southern Jordan*, PhD dissertation, University of California, San Diego. Available at <http://escholarship.org/uc/item/5f72d1xp>
- Ben-Yosef, E. (2012). Environmental constraints on ancient copper production in the Aravah Valley: Implications of the newly discovered site of Khirbet Mana'iyah in southern Jordan. *Tel Aviv*, 39/2: 58–74. <https://doi.org/10.1179/033443512X13424449373786>.
- Ben-Yosef, E. (2016). Back to Solomon's era: Results of the first excavations at 'Slaves' Hill' (Site 34, Timna, Israel). *Bulletin of the American Schools of Oriental Research*, 376: 169–198. <https://doi.org/10.5615/bullamerschoorie.376.0169>
- Ben-Yosef, E., & Levy, T.E. (2014). The material culture of Iron Age copper production in Faynan. In T.E. Levy, M. Najjar, & E. Ben-Yosef (Eds.), *New insights into the Iron Age archaeology of Edom, southern Jordan*, Vol. 2. Los Angeles: Cotsen Institute of Archaeology: 887–959.
- Ben-Yosef, E., Shaar, R., Tauxe, L., & Ron, H. (2012). A new chronological framework for Iron Age copper production at Timna (Israel). *Bulletin of the American Schools of Oriental Research*, 367: 31–71. <https://doi.org/10.5615/bullamerschoorie.367.0031>
- al-Bqā'in, F., Corbett, G.J., & Khamis, E. (2015). An Umayyad era mosque and desert waystation from Wadi Shīreh, southern Jordan. *Journal of Islamic Archaeology*, 2/1: 93–126. <https://doi.org/10.1558/jia.v2i1.26940>
- Bronk Ramsey, C. (2009). Bayesian analysis of radiocarbon dates. *Radiocarbon*, 51/1: 337–360. https://doi.org/10.2458/azu_js_rc.51.3494
- Damgaard, K. (2009). A Palestinian Red Sea port on the Egyptian road to Arabia: Early Islamic Aqaba and its many hinterlands. In L. Blue, J. Cooper, R. Thomas, & J. Whitewright (Eds.), *Connected hinterlands: Proceedings of Red Sea Project IV*. Oxford: Archaeopress: 85–97.
- de Jesus, P.S., Al-Sugiran, S., Rihani, B., Kesnawi, A., Toplyn, M., & Incagnoli, J. (1982). Preliminary report of the Ancient Mining Survey 1981 (1401). *Atlat*, 6: 63–96.
- Engel, T., & Frey, W. (1996). Fuel resources for copper smelting in antiquity in selected woodlands in the Edom highlands to the Wadi Arabah/Jordan. *Flora*, 191: 29–39.
- Erickson-Gini, T. (2014). Timna Site 2 revisited. In J.M. Tebes (Ed.), *Unearthing the wilderness: Studies on the history and archaeology of the Negev and Edom in the Iron Age*. Leuven: Peeters: 47–83.
- Fahn, A., Werker, E., & Baas, P. (1986). *Wood anatomy and identification of trees and shrubs from Israel and adjacent regions*. Jerusalem: Israel Academy of Sciences and Humanities.
- Glidden, H.W. (1941). Review of *The other side of the Jordan* by N. Glueck. *American Journal of Archaeology*, 45/1: 118–120.
- Glueck, N. (1935). *Explorations in eastern Palestine, II*. New Haven, CT: American Schools of Oriental Research.
- Glueck, N. (1940). *The other side of the Jordan*. New Haven, CT: American Schools of Oriental Research.
- Guilderson, T.P., Reimer, P.J., & Brown, T.A. (2005). The boon and bane of radiocarbon dating. *Science*, 307/5708: 362–364. <https://doi.org/10.1126/science.1104164>
- Haiman, M. (1995). Agriculture and nomad-state relations in the Negev Desert in the Byzantine and early Islamic periods. *Bulletin of the American Schools of Oriental Research*, 297: 29–53.
- Hauptmann, A. (2007). *The archaeometallurgy of copper: Evidence from Faynan, Jordan*. New York: Springer. <https://doi.org/10.1007/978-3-540-72238-0>
- Haviv, I. (2000). *Trekking and canyoning in the Jordanian Dead Sea rift*. Israel: Desert Breeze Press.
- Hayes, J.W. (1972). *Late Roman pottery*. London: British School at Rome.
- Heck, G.W. (1999). Gold mining in Arabia and the rise of the Islamic state. *Journal of the Economic and Social History of the Orient*, 42/3: 364–395. <https://doi.org/10.1163/1568520991208626>
- Heck, G.W. (2003). *The precious metals of West Arabia and their role in forging the economic dynamic of the early Islamic state*. Riyadh: King Faisal Center for Research and Islamic Studies.

- Ibrahim, K.M.d.K. (1989). *Wādī Raḥma 3049 IV* (map). 1:50,000. Amman: Royal Jordanian Geographic Centre.
- Ibrahim, K.M.d.K. (1991). *The geology of the Wadi Rahma, Map Sheet No. 3049 IV*. Amman: Geology Directorate, Geological Mapping Division.
- Ibrahim, M.M., & ElMahi, A.T. (2000). Metallurgy in Oman during the early Islamic period. In L.E. Stager, J.A. Greene, & M.D. Coogan (Eds.), *The archaeology of Jordan and beyond: Essays in honor of James A. Sauer*. Winona Lake: Eisenbrauns: 207–220.
- Jones, I.W.N. (2016). Beyond Iron Age landscapes: Copper mining and smelting in Faynan in the 12th–14th centuries CE. In S. McPhillips & P.D. Wordsworth (Eds.), *Landscapes of the Islamic world: Archaeology, history, and ethnography*. Philadelphia: University of Pennsylvania Press: 111–128. <https://doi.org/10.9783/9780812292763-008>
- Jones, I.W.N., Levy, T.E., & Najjar, M. (2012). Khirbat Nuqayb al-Asaymir and middle Islamic metallurgy in Faynan: Surveys of Wadi al-Ghuwayb and Wadi al-Jariya in Faynan, southern Jordan. *Bulletin of the American Schools of Oriental Research*, 368: 67–102. <https://doi.org/10.5615/bullamerschoorie.368.0067>
- Jones, I.W.N., Najjar, M., & Levy, T.E. (2014). 'Not found in the order of history': Toward a 'medieval' archaeology of southern Jordan. In S.D. Stull (Ed.), *From west to east: Current approaches in medieval archaeology*. Newcastle-upon-Tyne: Cambridge Scholars: 179–205.
- Jones, I.W.N., Najjar, M., & Levy, T.E. (In press). The Arabah copper industry in the Islamic period: Views from Faynan and Timna. In E. Ben-Yosef (Ed.), *Mining for ancient copper: Essays in memory of Prof. Beno Rothenberg*. Tel Aviv: Tel Aviv University Institute of Archaeology: 336–346.
- Kisnawi, A., de Jesus, P.S., & Rihani, B. (1983). Preliminary report on the mining survey, northwest Hijaz, 1982. *Atlat*, 7: 76–83.
- Levy, T.E. (1995). Cult, metallurgy and rank societies — Chalcolithic period (ca. 4500–3500 BCE). In T.E. Levy (Ed.), *The archaeology of society in the Holy Land*. London: Leicester University Press: 226–244.
- Levy, T.E., Najjar, M., & Ben-Yosef, E. (Eds.). (2014). *New insights into the Iron Age archaeology of Edom, southern Jordan*. Los Angeles: Cotsen Institute of Archaeology Press.
- Levy, T.E., Najjar, M., Gidding, A.D., Jones, I.W.N., Knabb, K.A., Bennallack, K., ... Balaswaminathan, S. (2012). The 2011 Edom Lowlands Regional Archaeology Project (ELRAP): Excavations and surveys in the Faynan copper ore district, Jordan. *Annual of the Department of Antiquities of Jordan*, 56: 423–445.
- Magness, J. (1993). *Jerusalem ceramic chronology: circa 200–800 CE*. Sheffield: JSOT Press.
- Magness, J. (2004). Khirbet Abu Suwwana and Ein 'Aneva: Two early Islamic settlements on Palestine's desert periphery. In D. Whitcomb (Ed.), *Changing social identity with the spread of Islam: Archaeological perspectives*. Chicago: The Oriental Institute of the University of Chicago: 11–23.
- Moskal-del Hoyo, M., Wachowiak, M., & Blanchette, R.A. (2010). Preservation of fungi in archaeological charcoal. *Journal of Archaeological Science*, 37(9): 2106–2116. <https://doi.org/10.1016/j.jas.2010.02.007>
- Najjar, M. (1989). Abbasid pottery from el-Muwaqqar. *Annual of the Department of Antiquities of Jordan*, 33: 305–322.
- Nevo, Y.D. (1991). *Pagans and herders: A re-examination of the Negev runoff cultivation systems in the Byzantine and early Arab periods*. Midreshet Ben-Gurion: IPS Ltd.
- Nol, H. (2015). The fertile desert: Agriculture and copper industry in early Islamic Arava (Arabah). *Palestine Exploration Quarterly*, 147(1): 49–68. <https://doi.org/10.1179/1743130114Y.0000000012>
- Peters, I., Tauxe, L., & Ben-Yosef, E. (In press). Archaeomagnetic dating of pyrotechnological contexts: A case study for copper smelting sites in the Central Timna Valley, Israel. *Archaeometry*.
- Petersen, A. (1994). The archaeology of the Syrian and Iraqi hajj routes. *World Archaeology*, 26(1): 47–56. <https://doi.org/10.1080/00438243.1994.9980260>
- Ponting, M.J. (2008). The scientific analysis and investigation of a selection of the copper-alloy metalwork from Tiberias. In Y. Hirschfeld & O. Gutfeld (Eds.), *Tiberias: Excavations in the House of the Bronzes, final report, volume I: Architecture, stratigraphy and small finds*. Jerusalem: Hebrew University: 35–61.
- Porath, Y. (2016). Tunnel-well (*qanat*) systems and settlements from the early Islamic period in the 'Arava. *'Atiqot*, 86: 1*–81*, 113–116. (In Hebrew with English summary).
- Power, T. (2012). *The Red Sea from Byzantium to the caliphate, AD 500–1000*. Cairo: American University in Cairo Press.
- Rapuan, Y. (2013). An early Islamic settlement and a possible open-air mosque at Eilat. *'Atiqot*, 75: 129–165.
- al-Rāshid, Sa'ad bin 'Abd al-'Azīz (1986). *Al-Rabadhah: A portrait of early Islamic civilisation in Saudi Arabia*. Essex: Longman.
- Reimer, P.J., Bard, E., Bayliss, A., Beck, J.W., Blackwell, P.G., Bronk Ramsey, C., & van der Plicht, J. (2013). IntCal13 and Marine13 radiocarbon age calibration curves 0–50,000 years cal BP. *Radiocarbon*, 55(4): 1869–1887. https://doi.org/10.2458/azu_js_rc.55.16947
- Rothenberg, B. (1962). Ancient copper industries in the western Arabah: An archaeological survey of the Arabah, part I. *Palestine Exploration Quarterly*, 94: 5–71. <https://doi.org/10.1179/peq.1962.94.1.5>
- Rothenberg, B. (1967). *Tsefunot Negev: arkhe'ologyah ba-Negev uva-'Aravah*. Ramat Gan: Masada.
- Rothenberg, B. (1972). *Were these King Solomon's mines? Excavations in the Timna Valley*. New York: Stein and Day.
- Rothenberg, B. (1988). Early Islamic copper smelting — and worship — at Beer Ora, southern Arabah (Israel). *Institute for Archaeo-Metallurgical Studies Newsletter*, 12: 1–4.
- Rothenberg, B. (1990). Copper smelting furnaces, tuyeres, slags, ingot-moulds and ingots in the Arabah: The archaeological data. In B. Rothenberg (Ed.), *The ancient metallurgy of copper: archaeology—experiment—theory*. London: Institute for Archaeo-Metallurgical Studies: 1–77.
- Rothenberg, B. (1999). Archaeo-metallurgical researches in the southern Arabah 1959–1990, part 2: Egyptian New Kingdom (Rameside) to early Islam. *Palestine Exploration Quarterly*, 131: 149–175. <https://doi.org/10.1179/peq.1999.131.2.149>
- Sabir, H. (1991). *Ancient mining and its impact on modern mineral exploration in Saudi Arabia*. (Technical Report No. BRGM-TR-11-3). Jeddah: Directorate General for Mineral Resources.
- Sauer, J.A. (1973). *Heshbon pottery 1971: A preliminary report on the pottery from the 1971 excavations at Tell Hesban*. Berrien Springs, MI: Andrews University Press.
- Schaefer, J. (1989). Archaeological remains from the medieval Islamic occupation of the northwest Negev Desert. *Bulletin of the American Schools of Oriental Research*, 274: 33–60.

- Schick, R. (2007). Al-Ḥumayma and the Abbasid family. In F. al-Khraysheh (Ed.), *Studies in the history and archaeology of Jordan IX: Cultural interaction through the ages*. Amman: Department of Antiquities of Jordan: 345–355.
- Shalev, S., & Northover, P.J. (1987). Chalcolithic metal and metalworking from Shiqmim. In T.E. Levy (Ed.), *Shiqmim I: Studies concerning Chalcolithic societies in the northern Negev Desert, Israel (1982–1984)*. Oxford: British Archaeological Reports: 357–371.
- Sharon, M., Avner, U., & Nahlieli, D. (1996). An early Islamic mosque near Be'er Ora in the southern Negev: Possible evidence for an early eastern qiblah? *Atiqot*, 30: 107–114.
- Shlomovitch, N., Bar-Matthews, M., Segev, A., & Matthews, A. (1999). Sedimentary and epigenetic copper mineral assemblages in the Cambrian Timna Formation, southern Israel. *Israel Journal of Earth Sciences*, 48: 195–208.
- Shmueli, O., Lender, Y., & Lifshits, V. (2013). Elat (southwest), Survey. *Hadashot Arkheologyot*, 125: http://www.hadashot-esi.org.il/report_detail_eng.aspx?id=2234&mag_id=120 (accessed 24 February 2016).
- Smith, A.M., II. (2014). The Southeast 'Araba Archaeological Survey. In S.T. Parker & A.M. Smith, II (Eds.), *The Roman Aqaba Project final report: Volume 1 – The regional environment and the regional survey*. Boston: American Schools of Oriental Research: 103–289.
- Smith, A.M., II, Stevens, M., & Niemi, T. (1997). The Southeast Araba Archaeological Survey: A preliminary report of the 1994 season. *Bulletin of the American Schools of Oriental Research*, 305: 45–71.
- Walker, B.J. (2012). The Islamic period. In J.A. Sauer & L.G. Herr (Eds.), *Ceramic finds: Typological and technological studies of the pottery remains from Tell Hesban and vicinity*. Berrien Springs, MI: Andrews University Press: 507–593.
- Weisgerber, G. (1987). Archaeological evidence of copper exploitation at 'Arja. *The Journal of Oman Studies*, 9: 145–238.
- Weisgerber, G. (2006). The mineral wealth of ancient Arabia and its use I: Copper mining and smelting at Feinan and Timna — comparison and evaluation of techniques, production, and strategies. *Arabian Archaeology and Epigraphy*, 17: 1–30. <https://doi.org/10.1111/j.1600-0471.2006.00253.x>
- Whitcomb, D. (1988). Khirbet al-Mafjar reconsidered: The ceramic evidence. *Bulletin of the American Schools of Oriental Research*, 271: 51–67.
- Whitcomb, D. (1989). Mahesh Ware: Evidence of early Abbasid occupation from southern Jordan. *Annual of the Department of Antiquities of Jordan*, 33: 269–285.
- Whitcomb, D. (1992). Reassessing the archaeology of Jordan of the Abbasid period. In S. Tell (Ed.), *Studies in the history and archaeology of Jordan IV*. Amman: Department of Antiquities of Jordan: 385–390.
- Whitcomb, D. (2006a). Land behind Aqaba: The Wadi Arabah during the early Islamic period. In P. Bienkowski & K. Galor (Eds.), *Crossing the rift: Resources, routes, settlement patterns and interactions in the Wadi Arabah*. Oxford: Oxbow: 239–242.
- Whitcomb, D. (2006b). Archaeological evidence of sedentarization: Bilad al-Sham in the early Islamic period. In S.R. Hauser (Ed.), *Die Sichtbarkeit von Nomaden und saisonaler Besiedlung in der Archäologie: Multidisziplinäre Annäherungen an ein methodisches Problem*. (Mitteilungen des SFB “Differenz und Integration”, 9). Saale: OWZ Halle: 27–43.
- Willies, L. (1990). Exploring the ancient copper mines of the Wadi Amram (South Arabah). *Institute for Archaeo-Metallurgical Studies Newsletter*, 15–16: 12–15.
- Willies, L. (1991). Ancient copper mining at Wadi Amram, Israel: An archaeological survey. *Bulletin of the Peak District Mines Historical Society*, 11/3: 109–138.
- Yekutieli, Y., Shilstein, S., & Shalev, S. (2005). 'En Yahav—A copper smelting site in the 'Arava. *Bulletin of the American Schools of Oriental Research*, 340: 1–21.
- Yisrael, Y. (2002). Be'er Ora (southeast). *Hadashot Arkheologyot*, 114: 102*–104*, 125–129. (In Hebrew with English summary).
- Al-Zahrani, A.A.A. (2014). *Mining in al-Baha region, south-western Saudi Arabia in Islamic-era: The archaeology of Asham*, PhD dissertation, University of York. Available at <http://etheses.white-rose.ac.uk/6483/>

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